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ORIGINAL ARTICLE

Fluoride content of bottled drinking waters available in Riyadh, Saudi Arabia

Abdullah M. Aldrees [a,*], **Saad M. Al-Manea** [b,1]

[a] *Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, P.O. Box 60169, Riyadh 11545, Saudi Arabia*
[b] *Saudi Specialty Certificate Program in Pediatric Dentistry, P.O. Box 2487, Riyadh 11451, Saudi Arabia*

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KEYWORDS

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Abstract *Aims:* This study aimed to examine the fluoride concentration of commercially available bottled water products in Riyadh, Saudi Arabia, and to assess the accuracy of the labeling of fluoride concentration on the tested brands.
Methods: Fifteen randomly selected commercial brands of bottled water were obtained from supermarkets in Riyadh, Saudi Arabia. Three bottles of each brand were purchased, and fluoride content was measured using a combination fluoride-ion-selective electrode. The average reading for each brand was estimated and also compared with the fluoride content printed on the label.
Results: The mean (±SD) fluoride content of the 12 local bottled water samples was 0.79 (±0.09) mg/L with a range from 0.5 to 0.83 mg/L. The mean fluoride concentration of the three imported brands was 0.67 (±0.02) mg/L with a narrow range of fluoride content (0.65–0.69). All tested samples mention the fluoride content on the label except two imported brands. Five samples showed a significant difference between our evaluation and stated content of fluoride that ranged between +0.46 and −0.2 mg/L.
Conclusions: Bottled drinking waters available in Riyadh, Saudi Arabia contain differing concentration of fluoride, but within a safe range for use as a source of systemic fluoride. In addition, the manufactures' labeling of fluoride content may be inaccurate.

* Corresponding author. Tel.: +966 1 4676057; fax: +966 1 4679017.
E-mail addresses: amaldrees@ksu.edu.sa (A.M. Aldrees), smanea@hotmail.com (S.M. Al-Manea).
[1] Tel.: +966 1 2055050; fax: +966 1 2056060.

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1. Introduction

One of the most common trends among consumers in recent years in various countries, including Saudi Arabia, is the replacement of their daily water intake with bottled water, possibly due to apprehension about contaminants in natural water supplies (Ahiropoulos, 2006; Toumba et al., 1994). Sales of bottled water have increased and different types and brands of bottled water are available in Saudi Arabia supermarkets. The substitution of commercial drinking water with bottled

water is a serious concern because the benefit of drinking fluoridated water may be lost. The dental caries reduction that derived from drinking fluoridated water is well documented and water fluoridation is considered an economical and safe preventive measure (Weinberger, 1991).

Effective and safe preventive fluoride programs require an awareness of the exact concentration of drinking water either public or bottled. When prescribing fluoride supplements, dentists should be aware of the fluoride content of bottled waters used by child patients, especially brands with a concentration higher than 0.3 ppm (Ahiropoulos, 2006). In addition, the fluoride content of the bottled water may be highly variable among different brands, and that may cause dental fluorosis especially in infants and children when receiving greater concentration than the optimal levels recommended for their age group (Ahiropoulos, 2006). Manufacturers are encouraged to list the nutritional contents of their product but labeling of the fluoride levels of the products may not be legally required in some countries and even when fluoride concentration appears on the bottle labels, they may not always be accurate (Ahiropoulos, 2006).

Previous research attempts to evaluate the concentration of fluoride in bottled water were made in several countries. Most of the early projects found that most of the commercially available bottled water failed to list the fluoride content (Studlick and Bain, 1980; McFadyen et al., 1982; Stannard et al., 1990). Weinberger evaluated 17 brands in Canada and he concluded that there was a great variation in fluoride concentration between the products and that ranged between 0.06 and over 4 ppm (Weinberger, 1991). Toumba et al. (1994) found that the manufacturers' labeling of fluoride concentrations of bottled drinking waters in Leeds, United Kingdom are mainly inaccurate. In a study conducted in Greece, Ahiropoulos saw a wide range (0.05–4.8 mg F/L) of fluoride content in 22 randomly selected commercial brands of bottled water (Ahiropoulos, 2006). Cochrane et al. (2006) evaluated 10 brands of bottled waters in Australia and concluded that all brands tested contained negligible fluoride which justifies the concern that regular consumption of bottled water may reduce the benefits gained from water fluoridation. In West Virginia, only three brands out of 65 brands tested by Johnson and DeBiase contained a fluoride concentration consistent with that listed on the label or as identified by the manufacturer (Johnson and DeBiase, 2003). When several batches of the same brand were examined, Bartels et al. (2000) found significant differences in fluoride concentrations between the batches of three brands out of five tested. The variability in the fluoride content of bottled water was also reported recently by Quock and Chan who found a concentration that ranged between 0.32 and 0.63 ppm (Quock and Chan, 2009).

In Saudi Arabia, few reports have been published about the fluoride content of local and imported bottled water. Nineteen locally produced and eight imported bottle water were analyzed by Alabdula'aly and he found the fluoride level to be between 0.2–0.83 and 0.04–0.2 mg/L for the locally produced and imported waters respectively (Alabdula'aly, 1997). Alabdula'aly and Khan (1999) have also evaluated bottled water in Riyadh and they reported that fluoride was found below the Saudi Arabian Standards Organization recommended limits in two of the local brands whereas fluoride levels in all of the imported brands were below the recommended values. A similar result was reported by Zahid who found that the fluoride concentrations in two local and six imported brands were below the lower limit recommended by the Saudi standards (Zahid, 2002). Paul et al. (1998) have reported the fluoride content from the label of 26 brands of still and sparkling water available in Saudi Arabia, and they have found that the Saudi brands range of labeled fluoride concentration was 0.5–0.8 mg/L. Most of the imported brands studied did not indicate their fluoride content on the labels. A recently published report by Khan and Chohan has shown that in 21 different brands of locally produced bottled drinking water in Riyadh, 19 contained higher levels of fluoride than the label values. The laboratory findings of fluoride concentration ranged between 0.32–1.1 ppm with a mean value of 0.86 ppm (SD $\pm$0.16) (Khan and Chohan, 2010).

Knowledge of the fluoride content of the drinking water is essential to all health care professionals especially dentists. Planning of preventive dental programs and prescription of fluoride supplements would depend on a recent and accurate assessment of the current fluoride intake habits by the population. For this reason, the need for more studies that examine the commercially available bottled water in Saudi Arabia and report the findings in the dental literature is obvious.

This study aimed to examine the fluoride concentration of commercially available bottled water products in Riyadh, Saudi Arabia, to determine if significant differences existed among the products, and to explore packaging date as a variable on the concentration of fluoride. In addition, the study aimed also to assess the accuracy of the labeling of fluoride concentration on the tested brands.

2. Materials and methods

Fifteen brands of bottled water were obtained from 4 supermarkets in Riyadh, Saudi Arabia. Of these, 80% (12 brands) had their source or production site in Saudi Arabia and 3 (20%) were imported. Three bottles from each brand, each with a different batch number and date of bottling, were purchased. All bottles were stored in a dark place and in their original closed plastic containers at room temperature until the fluoride analysis was made.

After shaking the bottle of water, a 50-mL sample was taken and kept in container, then coded so the type and the brands were unknown by the technician testing the water. Water samples were diluted with equal quantities of TISAB (Total Ionic Strength Adjustment Buffer) and the fluoride-ion concentration was determined using a combination fluoride-ion-selective electrode (Metrohm, 605 ion-selective Metrosensor Electrodes, 6.0502.150, FL, USA) and by reading a digital readout ion-meter (Metrohm, pH/ion-meter, Model 781, FL, USA) (Christian, 2004). The samples and fluoride standard solutions (0.2, 0.4, 0.6, 0.8 and 1 ppm) were diluted with the TISAB. The solutions, which contained 25 ml of the sample and 25 ml of TISAB solutions, were mixed with a magnetic stirrer for 3 min. The electrode potentials of the sample solutions were directly compared with those of fluoride standard solutions.

Two readings were taken for each sample then the average was recorded. To assess the reliability of the method, one batch number (of three) for each of the bottled water samples was randomly selected and the samples were re-analyzed. SPSS (Statistical Package for Social Science, version 16) was used to derive descriptive data. Paired *t*-test and correlation analysis were employed to compare the first and second measurements

of the samples; Kruskal–Wallis test was used to compare the fluoride concentration in the samples, while Mann–Whitney test was used to evaluate the differences between local and imported products.

3. Results

The accuracy of the method was confirmed by comparing the first and second readings of the samples, and the differences were not statistically significant ($P = 0.24$). The correlation between the measurements was $r = 0.996$ ($P < 0.0001$), and the mean (±SD) difference was 0.019 (±0.01) mg/L. The concentrations of fluoride in the 15 different types of drinking waters are shown in Table 1. For each water sample the concentration is shown in mg/L fluoride depicted on the label (or NM if not mentioned) and as determined by the experiments. The mean (±SD) fluoride content of the 12 local bottled water samples was 0.788 (±0.09) mg/L with a range from 0.502 to 0.832 mg/L. Differences between these brands were statistically significant ($P = 0.037$). With an exception of Arwa® brand, all bottled water samples showed a consistent fluoride concentration in the three batches with a range of less than 0.1 mg/L.

The mean fluoride concentration of the three imported brands was 0.669 (±0.02) mg/L with a narrow range of fluoride content (0.646–0.694). When local and imported wasters were compared, the difference was statistically significant ($P = 0.0001$).

Regarding the quality of the labeling of bottled waters, only two imported brands (Volvic®, Evian®) did not state the fluoride concentration on the label. Most of the labeled fluoride concentration of the bottled water samples was in agreement with our measures. However, two samples had significantly higher level than stated on the label. One of the samples (Arwa®) listed the level at <0.1 mg/L fluoride on the label and we measured a value of 0.502 mg/L. Another brand (Tannourine®) was found to contain 0.665 mg/L fluoride but it listed a fluoride level at <0.2 mg/L on the label. Three samples (Safa®, Aquafina®, and Mozn®) had a lower level of fluoride than stated on the label with a difference of approximately 0.2 mg/L. The fluoride content between batches of the studied brands was found to be variable, however, the differences were not statistically significant ($P = 0.95$).

4. Discussion

The concentration of fluoride in the bottled drinking waters purchased from Riyadh supermarkets was found to vary between 0.50 and 0.83 mg/L fluoride. These results were different from earlier studies that reported a wider range of fluoride content in the water samples evaluated in Saudi Arabia (Alabdula'aly, 1997; Alabdula'aly and Khan, 1999; Zahid, 2002), but they were in agreement with Al-Oud who reported that the fluoride concentration of 24 locally produced bottled water samples investigated falls exclusively within the range of 0.6–1 mg/L (Al-Oud, 2004). Although the reported range of fluoride content in the locally produced brands by Khan and Chohan was wider (0.32–1.1 mg/L), the means of the present study and their study were comparable (0.788 and 0.86 mg/L, respectively) (Khan and Chohan, 2010). In their study, Khan and Chohan have analyzed 21 different brands that were collected from Riyadh in year 2004, and only one batch was tested (Khan and Chohan, 2010). None of the imported brands had fluoride concentration below 0.6 mg/L, and only one out of the 12 local brands tested had fluoride content below that level. In addition, this study reported a narrow range in the fluoride concentration within the same brand in different batches with an exception of one sample. These results disagree with earlier studies that reported significant differences in fluoride concentrations between the batches of water products (Bartels et al., 2000; Quock and Chan, 2009). It has been shown that the fluoride content of water depends on weather

Table 1 Fluoride concentration (mg F/L) of three different batch numbers of each bottled water, measured twice each, and the mean (±SD) fluoride content.

Bottled water brand	Source	Labeled content (mg F/L)[a]	Fluoride concentration (mg F/L)			Mean ± SD fluoride concentration (mg F/L)
			Batch 1	Batch 2	Batch 3	
Safa	Makkah	1.0	0.819	0.805	0.783	0.802 ± 0.02
Nova	Riyadh	0.8	0.798	0.806	0.794	0.799 ± 0.01
Nestle	Riyadh	0.9	0.852	0.828	0.803	0.827 ± 0.03
Hana	Alqassim	0.85	0.807	0.816	0.794	0.805 ± 0.01
Hada	Makkah	0.8	0.847	0.819	0.813	0.826 ± 0.02
Alqassim	Alqassim	0.95	0.826	0.802	0.772	0.800 ± 0.03
Aquafina	Riyadh	1.0	0.808	0.809	0.803	0.806 ± 0.01
Arwa	Riyadh	<0.1	0.444	0.576	0.487	0.502 ± 0.07
Afnan	Riyadh	0.8–1.2	0.840	0.823	0.834	0.832 ± 0.01
Hilwa	Jouf	0.8	0.863	0.805	0.827	0.831 ± 0.03
Mozn	Jazan	1.0	0.806	0.787	0.805	0.799 ± 0.01
Almanhal	Riyadh	0.9	0.835	0.806	0.817	0.819 ± 0.02
Tannourine	Lebanon	<0.2	0.645	0.685	0.667	0.665 ± 0.02
Volvic	France	NM[b]	0.701	0.683	0.698	0.694 ± 0.01
Evian	France	NM	0.592	0.680	0.667	0.646 ± 0.05

[a] mg/L fluoride is equivalent to ppm fluoride.
[b] NM = not mentioned.

changes including heavy rains; so, seasonal fluctuations may explain the variations in fluoride concentrations within the same drinking water product (Grobler et al., 2001).

The level of fluoride in the bottled drinking waters has implications for prescription of fluoride supplements as well as for possible fluorosis. The American Dental Association continues its endorsement of fluoridation of community water supplies in order to adjust the natural level of fluoride to a concentration sufficient to protect against tooth decay, a range of from 0.7 to 1.2 ppm (ADA, 2002). Recommended level of fluoride in the water for warm countries like Saudi Arabia should be in the range of 0.6–0.7 ppm, due to the larger amount of water consumption in the hot climate compared to the temperate countries (AlDosari et al., 2003). The American Academy of Pediatric Dentistry recommends that fluoride supplements should be considered for all children drinking fluoride-deficient (<0.6 ppm) water. After determining the fluoride level of the water supply or supplies (either through contacting public health officials, or water analysis), evaluating other dietary sources of fluoride (especially that certain foods and beverages e.g. tea contain high fluoride levels), assessing the child's caries risk, the daily fluoride supplement dosage can be determined using the Dietary Fluoride Supplementation Schedule (Burt, 1992; Levy et al., 1995; AAPD Reference Manual, 2008).

Based on this study results, routine consumption of the tested locally produced bottled drinking waters by infants and children provides adequate prevention against dental caries. More studies will be required to evaluate the fluoride content of the baby formulas that have been shown to contain variable amounts of fluoride for accurate estimation of fluoride intake by babies (Pagliari et al., 2006; Buzalaf et al., 2004). Elevated level of fluoride in a child's drinking water could result in fluorosis. While none of the tested bottled drinking waters contain more than 1 mg/L fluoride, though extremely high fluoride concentration (up to 4.8 mg/L) in bottled drinking water has been reported (Ahiropoulos, 2006). Studies that assessed the fluoride level in main drinking water in different provinces in Saudi Arabia have shown that fluoride levels vary widely between 0.00 and 6.20 ppm, and the populations living in these regions are not always exposed to adequate fluoride levels (AlDosari et al., 2003). The current analysis of locally produced bottled water indicates that the use of these products supplies more optimum and consistent amount of systemic fluoride compared to the more varying municipal network water and well water.

Most of the tested samples displayed the fluoride content of the water on the labels. Only two imported brands did not list the fluoride content. This was not the case for many of the products tested in other countries. For example, Ahiropoulos studying water products in Greece, found that only 18% displayed the content of fluoride (Ahiropoulos, 2006), and in Toumba et al. (1994) study, only 58% of the bottled waters stated the fluoride concentration on the label. Our findings indicated that eight out of the 13 samples evaluated showed a similarity between the measured fluoride content and that marked on the label. However, five samples showed a significant difference between our evaluation and stated content of fluoride that ranged between $+0.46$ and -0.2 mg/L. Dentists should be aware that values on the labels might not be reliable when considering fluoride supplementation for children. In addition, quality control needs more close supervision on the part of drinking water factories to monitor the content of fluoride and other minerals and to accurately label their products.

5. Conclusions

Bottled drinking waters available in Riyadh, Saudi Arabia contain differing concentration of fluoride, but within a safe range for use as a source of systemic fluoride. Not all the products display the fluoride concentration on the label. In addition, the manufactures' labeling of fluoride content may be inaccurate.

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